Summary of stakeholder experts panel

National stakeholders meeting

In April 2008, as part of the Alternative Feeds for Aquaculture Initiative, the agencies held a national stakeholder meeting in Silver Spring, Maryland (see agenda on line at http://aquaculture.noaa.gov/news/feeds.html#results). The purpose of the meeting was to provide a forum for open communication among stakeholders including scientists, representatives from government and non-governmental organizations, academia, private industry, and others regarding trends, opportunities, challenges and key issues related to the development of alternatives to fish meal and oil in aquaculture diets. The meeting attracted over 60 participants. Four major topics were addressed, including human health and product quality, environmental implications, alternative feedstuff options, and future directions for feeds manufacturing. This chapter is intended to provide an overview of the stakeholder meeting, including the expert presentations and stakeholder discussions.

Dr. Charles Santerre, Dr. Jane Lubchenco, and Dr. Paul Sandifer (standing), at the national stakeholder panel meeting in April 2008

Hosted by NOAA's Aquaculture Program, the meeting was brought to order by Dr. Michael Rubino, the agency's Aquaculture Program Manager. Dr. Rubino set the stage with background information on the pressing need for the rapid development, testing, and commercialization of alternative feed ingredients. He also presented the challenge to the group from the standpoint that the environmental and financial sustainability of aquaculture depends on developing alternatives to fish meal and fish oil as the primary feed ingredient. Furthermore, he stressed that the nutritional characteristics of fish meal and fish oil-based feeds, including essential fatty acids, are integral to what make fish and shrimp a healthy food choice from a human health perspective. He also posed several critical questions to the group, as well as to the broader aquaculture and seafood communities and policymakers, including:

- Which alternatives are most promising?
- Which deserve our attention?
- Which deserve our federal research dollars?

The meeting was moderated by Dr. Paul Sandifer, then the Senior Scientist for Coastal Ecology for NOAA's Ocean Service. Dr. Sandifer is now the acting-Senior Science Advisor to NOAA Administrator Dr. Jane Lubchenco. He set the tone for the meeting with the following observations:

- It is clear the increasing human population has an increasing demand for seafood, and even in the most optimistic of scenarios, we have a fully developed wild fishery situation, stable or declining. There simply is not much more we can take from the oceans.
- We need aquaculture, but we need aquaculture to be a sustainable green industry—to have as little negative and as great a positive impact as possible.
- The concern is that increasing demand could put unsustainable pressure on wild capture fisheries.
- There is also the question of the economic sustainability of aquaculture -- increasing costs and increasing demand will continue to result in higher costs and more competition for fish meal and fish oil.
- In aquaculture we are dealing with controlled feeding, not the ability of animals to graze in the natural environment. We need to take advantage of this. Rather than using more and more wild capture fishery products, we need to figure out how we can better supply the essential amino acids and essential fatty acids from other ingredients.
- There is considerable difference of opinion about the best uses for the natural feed ingredients. The bottom line is that unless alternative feedstuffs are found, demand for aquaculture will surely outpace affordable supply. So whether you look at this

from the environmental or ecological perspective or you look at it strictly from the business perspective—better yet, look at it from both perspectives—the development of alternatives to fish oil and fish meal in aquaculture feeds is essential.

Providing the USDA research perspective on alternative feeds, Dr. Caird Rexroad, Associate Administrator for the USDA's Agricultural Research Service (ARS), presented an overview of the agency's commitment to aquatic animal nutrition including alternative feeds. He discussed challenges, issues of competition, and options to advance the field of aquaculture nutrition.

He noted that the current competition between food and fuels is an issue that is just now being felt by Americans, and this issue will continue to place challenges on future uses of feedstuffs as well as the economics of agriculture and aquaculture. He also noted that a key scientific tool to address many of the feeds issues is genomics. . . . "(genomics) will be a big part of anything that we use as we try to understand nutrition and the response of these species in breeding to alternative feed sources."

Dr. Ralph Otto, Associate Administrator of the Cooperative State Research, Education and Extension Service (now the National Institute of Food and Agriculture, NIFA) opened his remarks about the variety of strategies required to address the very real challenges and changes facing agriculture and aquaculture on a recurring basis. This included the critical need both domestically and globally to identify and incorporate new and practical alternatives for fish meal and oil in feeds for aquatic animals. He stressed the added challenge of maintaining and even enhancing the human health benefits of consuming farmed aquatic foods as well as protecting sensitive natural resources associated with aquatic production sites. He also noted that successful strategies are developed at these types of meetings that join people of diverse interests, knowledge, and even sometimes competing interests, but keenly focused on pathways for solutions rather than problems and obstacles.

He stated that NIFA is a grant funding agency working across the broad spectrum of agriculture and in partnership and support of the land grant university (LGU) system with research, education and extension programs, some of which include aquaculture. NIFA also shares resources and people with ARS through numerous co-located laboratories at LGU and also with NOAA Sea Grant extension programs.

He explained that NIFA recently expanded integrated programs that include research, extension and/or education to mobilize expertise across these functional programs on distinct problem areas taking full advantage of multidisciplinary and collaborative approaches for solutions that equate well with the challenges that will be addressed at this

meeting. He stressed a real challenge is how to most effectively focus basic research on the most critical problems and efficiently translate increased understanding of complex systems and processes to applied research and practical applications cost-effectively. Science moves our knowledge system forward and can create new visions and possibilities for today and in our future. Dr. Otto asked the participants to imagine a world where foods from aquaculture not only provide fundamental nourishment but also improve our day-to-day health and contribute to clean water, clean air, and a sustainable environment. He noted that the US Department of Agriculture was created by President Abraham Lincoln and in his last public address he reminded us that important principles may and must be flexible. Dr. Otto challenged the participants to be flexible and move forward in a way that anticipates not only what is but what can be as new ideas emerge to stimulate critically needed progress and solutions on alternatives to fish meal and oil in aquatic animal feeds.

Following these opening remarks, four overarching issues were introduced by recognized experts including Dr. Charles Santerre of Purdue University (human health and product quality), Dr. Jane Lubchenco then of Oregon State University and now the current NOAA Administrator (environmental implications), Dr. Diane Bellis of Ag Source, Inc. (alternative feedstuff options), and Mr. Richard Nelson of Silver Cup Feeds (future directions for feeds manufacturing). Following the introductory presentations, breakout groups for the four issues provided focused discussion on specific challenges, status, needs and research priorities, and mechanisms to facilitate progress.

Human health and product quality impacts

Dr. Charles Santerre provided an overview of the health benefits of seafood and a human health perspective of the role of seafood in diet. His presentation is available online at: http://aquaculture.noaa.gov/news/feeds.html#results. Highlights from Dr. Santerre's presentation included the following points:

- The old saying "you are what you eat" applies to fish as well. The nutritional value of fish is based on their diet. What is in the diet of fish will be ingested by humans.
- The nutrients in fish include the healthy omega-3 fatty acids (EPA and DHA), selenium, calcium, iodine, zinc, vitamin D, arginine, conjugated linoleic acid, and polyphenols among others;
- Fish ingest these key nutrients as part of their diet and then pass them on to humans. We need to pay attention to the impact of changes to fish feed because those changes may impact human health.
- Three and one-half ounces of salmon contains 90 percent of the recommended daily allowance (RDA) of vitamin D for an adult and fish can be an excellent vehicle for getting vitamin D into the human diet.
- DHA is one of the essential omega-3 fatty acids and is important early in life for healthy brain and eye development. Later in life, these nutrients are also important.
- Drs. Dariush Mozaffarian and Eric Rimm of the Harvard Medical School published the results of a landmark study in 2006 that determined the impact of fish consumption on human heart health looking at mortalities from sudden cardiac death. The study found that the long chain omega-3 fatty acids (EPA and DHA) contained in fish protect the heart during a heart attack. Their work found that one to two servings of fish per week; especially species higher in EPA and DHA, reduces the risk of coronary death by 36 percent and reduces total mortality by 17 percent.
- Based on the American Heart Association's estimate of more than 300,000 deaths every year due to sudden cardiac death, 120,000 lives could be saved every year if people would consume more fish or fish oils that contain the omega-3 fatty acids, EPA and DHA.
- Omega-3 fatty acids are important for our brain health as we age. One study, published by Dr. Martha Clare Morris at the Rush Institute, showed that individuals consuming one fish meal per week had a 10 percent slower cognitive decline. Further, those consuming two fish meals per week had a 13 percent slower cognitive decline.
- Americans are currently eating about 16 pounds of seafood per person per year, which is about half the amount needed to realize the full benefits.

- Nutritionists keep encouraging consumers to eat 8 ounces of seafood per person per week—or two seafood meals per week—to gain the health benefits.

Dr. Santerre noted that the potential and the challenge for aquaculture is supplying healthy seafood in an economically and environmentally sustainable manner. Increasing the array of suitable feed ingredients will improve the stability of supply and the sustainability of aquaculture.

Dr. Santerre's recommendations to achieve greater supply and sustainability of healthy seafood included:

- Improved nutrient content information for all seafood.
- Use of biotech crops designed to contain DHA and EPA.
- Need for fish nutritionists, human nutritionists, food scientists, and others to work collaboratively to explore farmed seafood as a "functional" food.
- Increased amount of fish in the marketplace, especially those species that provide the important nutrients.

Environmental implications

Dr. Jane Lubchenco provided an overview of the concept of ecological services and the complex but integral interactions of ecosystems and impacts caused by human activity. In her presentation, which is available online at: http://aquaculture.noaa.gov/news/feeds.html#results, she described the concept of the millennium ecosystem assessment, which relates the ecological service benefits that are provided to people by the functioning of ecological systems, and how society is doing in maintaining these critical services. These benefits include food, climate regulation, purification of air and water, and protection of coasts against storms, among others. The millennium ecosystem assessment concluded that 60 percent of the ecosystems for which enough information exists are in decline. A key example of an ecological service in decline is capture or wild-caught fisheries. Agriculture and aquaculture, however, are on the increase.

The modification or conversion of an ecosystem results in a tradeoff of ecological services—e.g., when mangrove ecosystems are developed for shrimp production or another form of agriculture. An intact mangrove ecosystem provides nursery habitat critically important to many species, seafood, fuel, and timber. In addition, mangroves act as sediment traps, which prevent sedimentation of coastal habitats including reefs. Furthermore, the Indian Ocean tsunami showed how mangroves play a critically important role in protecting shorelines against erosion, absorbing the energy of storms. As mangroves are converted to homes, shrimp ponds, or agricultural crops, certain services are gained and others lost.

The oceans are another example. This ecosystem once was considered a frontier, with new fisheries to be discovered and new species to be caught and captured. Now those resources are in decline. According to Dr. Lubchenco, "It is important to understand that it's not just a particular activity that needs to be sustained through time, but that the inputs to that system and the outputs from that system need to be sustainable in the larger context. It's not just about growing more of something; it's about doing it in a way that does not negatively impact the provision of other ecosystem services."

Dr. Lubchenco suggested several possible solutions to helping to make aquaculture more sustainable, including:

- Consider all the implications of any feed source—for example, shifting to by-catch of non-target species might be problematic for the same reasons that fishing on small pelagics more and more is problematic, in terms of the disruption it would likely cause to many food webs.
- Terrestrial plants, bacteria, microalgae, protists, and yeasts are worth exploring.
- Better use of seafood products that are already being processed.
- Perhaps marine invertebrates, i.e., marine polychaetes (worms).

Alternative feedstuffs options

Dr. Diane Bellis discussed the necessity and opportunities for development of alternative aquaculture feeds, and provided an overview of the Plant Products and Aquafeed Working Group. The group is a coalition of researchers with a goal of coordinating research, exchanging data, and establishing standards for research on plant-based feeds. In her presentation, which is available online at: http://aquaculture.noaa.gov/news/feeds.html#results, she stated that the demand for alternatives to fish oil and fish meal will continue to be strong, even when the demand for food and energy creates competition globally. She also stated that soybeans have been and will continue to be a part of future efforts in increasing alternative feedstuffs in aquaculture feed. A number of characteristics and factors of soy make it an important feedstuff:

- Soy has the best balanced profile among plant proteins.
- Soy accounts for 70 percent of the world's protein meal consumption.
- In the United States, 98 percent of the soybean meal is used in animal feed, primarily for poultry and swine.
- Aquaculture is the fastest growing segment of the market for U.S. soybeans.
- The United States exports about $9 billion worth of soybeans annually, nearly equal to the amount of the U.S. seafood trade deficit.

Challenges pertaining to soybeans and their use as an aquaculture feed ingredient also exist. Ninety percent of soybean oil is currently used for human consumption, leaving 10 percent for other uses including aquafeeds. It boils down to an economic and human nutrition issue as to use of oils. Development of alternative feedstuffs and sustainability will be a function of well-funded, strategic, highly credible research. Development must be neutral or beneficial to the ocean ecology, economically viable, and technically feasible. The road to this development will be rocky. We know relatively little about 25,000 species of fish. There are about 3,000 marine species that we eat, and 220 fish species of economic interest. The variation of nutritional needs is extremely wide and only a few fish species have been bred for production. Furthermore, those species have yet to be bred for improved efficiency at digesting any protein, let alone plant or other alternative proteins.

Progress has been made, but results are most often limited and confusing and come at a high price. All the research tools and breakthroughs have yet to be used effectively and the investment must be expanded to effect tangible progress. We need to learn to feed new fish species efficiently and sustainably–thus the Plant Products and Aquafeed Working Group and their efforts.

Alternative feedstuffs options

The working group's first effort was a review paper that formed the basis for the plant products and aquafeeds strategic research plan, which outlines seven goals with performance measures:

1. Improve the quality of reporting on feeding trials, the different techniques used, and formation of standard approaches and protocols;
2. Use genomics to match feed with animals;
3. Improve plant quality;
4. Explore gut microflora and probiotic aspects;
5. Processing to optimize the efficiency of feeding these plant-based diets;
6. Expand marketability of the product–characteristics for human consumption; and
7. Keep the organization moving and making the data available to people who can use them.

Soybean farmers are committed to these efforts and have funded three projects: development of a control line of fish with known genetics; a large feeding trial feeding low phytate soybeans to fish; and a synthesis of the literature to identify the gaps. Dr. Bellis recommended that the NOAA-USDA Alternative Feeds Initiative include the following:

- Develop a road map for identifying the research needed beyond plant-based diets, for including other alternatives, and build on the process that the PPA has developed.
- The Joint Subcommittee on Aquaculture can play an increased role in this effort, and it is critical that all federal agencies having a stake in aquafeeds be actively involved.

Feed manufacturing challenges

Richard Nelson, of Nelson and Sons, Inc. highlighted the fact that fish farmers focus on four basic and interrelated elements:

1. Create a healthy animal in its environment;
2. Grow that animal to a market size and sell it;
3. Deal with the metabolic waste that occurs on the farm that can have an environmental, regulatory, and water quality impact; and
4. Be able to make it all work economically—the farmer doesn't want to go into the business of losing money or breaking even.

Mr. Nelson noted that for each emerging species or every known species, a tremendous amount of work goes into the research to understand the nutrient requirements of that fish. Algae-based DHA oils are of much interest and ". . . guys like me are on the edge of our seats waiting for this to come out onto the marketplace and be produced at such a rate that the economics of it will make sense." He also noted that the feeds industry is moving toward increasing the nutrient density of the feeds to lower the food conversion ratios (FCRs). "The better we do that, the better growth we get, and the less metabolic waste we introduce into the environment," he said.

"We have been practicing the art of alternative and replacement proteins for 30 to 40 years. What has driven the industry to make changes in terms of the use of fish oil and fish meal hasn't been driven by environmental pressure, and it hasn't been driven by regulations; it's been driven by *economics*."

Breakout groups

Following the expert presentations, the participants self-selected into four breakout groups for discussions. The four topics were:

- Human health and product quality, led by Dr. Michael Rust;
- Environmental implications, led by Dr. Jeff Silverstein;
- Alternative feed stuffs, led by Dr. Rick Barrows; and
- Manufacturing challenges and future directions, led by Charlotte Kirk-Baer.

Human health & product quality

Human health and product quality

The charge to this breakout group was to address the following questions:

1. What aspect of seafood's effect on human health is most important to you or your constituents or the consumer? How important is seafood as an alternative to red meat for cardiovascular benefits, for neurological development in children or other health benefits. How might alternative feeds affect this concern?
2. What aspect of seafood's product quality is most important to you? What is the relative appeal on nutritional health benefits versus the perceived risks form chemical contamination and toxins? How might alternative feeds affect this concern?
3. What is the best way to develop and communicate information on health benefits and product quality of seafood reared on alternative feeds to enhance consumer confidence? Who should be developing and communicating this information to the consumer – industry, NGO's, government, academia, or collaborations of these?
4. What makes seafood unique in delivery of healthy compounds (high protein, low saturated fats, high omega-3 fatty acids, vitamins)? Will alternative feeds reduce the appeal of seafood?

The group discussed and outlined key questions or needs to address regarding human health and product quality as follows:

Key health considerations

- Change in fatty acid profile, n6:n3
- Se, Zn, micro and macro minerals (except iron)
- Supplements vs. fish
    - o Benefit analysis
    - o Affordability
    - o Digestion problems
    - o Other nutrients
        - i. Taurine
        - ii. Astaxanthin
        - iii. Vitamin D

"Designer food" to target specific health issues–priorities

- Collaboration among fish nutrition, food safety and human nutrition
- Establish database of feed ingredients
- Development of functional foods
- Maintaining/increasing supply of fish
- Development/use of models to explore impacts of diet shifts in
  - o Human consumption of fish on human health
  - o Fish diets on human health
- Develop reference list of nutrient composition of feedstuffs

Product quality

- Taste, palatability, texture
- Cultural identity–indigenous species
- Shelf life

Environmental implications

This breakout session was challenged to address the following questions:

1. What are the key metrics for alternative protein and oils (costs, availability, and carbon footprint)? How can we incorporate value of the environmental impact or lack of impact?
2. Of the possible alternatives to pelagic fishery derived proteins and oils, are there some that are more appealing form an environmental perspective? Who should take the lead to develop these alternatives?
3. Can we identify benefits to the environment that are direct and or indirect of reducing the use of pelagic fishery derived proteins and oils?

The group focused on the metric relating the decision process for evaluating environmental impacts of feeds and alternative sources of protein and oils:

Alternative sources of protein and oils key metrics:

- Product quality–omega-3 fatty acids
- Feed efficiency
- Suitability–nutrients
- Species–specific needs

Specific environmental questions/concerns were listed and discussed including:

- Processing wastes
- Economic feasibility
- Long-term impacts
- Ecosystem bioaccumulation
- Local availability–compare domestic vs. foreign
- Major vs. supplemental ingredients
- Complete replacement?

Breakout groups

Environmental implications

- Consequences of genetically selected organisms/interactions
- Ecosystem impacts of nutrient extraction
- Perception of environmental impact
- Carbon footprint analysis
- Conversion ratios of poor alternatives e.g. insects minimize inputs
- Byproducts–reuse, recycle, etc.
- Toxins, contaminants, excess nutrient release (e.g. phosphorus in Idaho)
- Standards/protocols for feed trials (e.g. waste)
- Consumer Information
- Framework for evaluating environmental impacts
- Life cycle analyses
- Genetic diversity
- Green house gas and equivalents
- Regulatory solutions
- Energy exchange

Alternative feed ingredients and approaches could include:

- Determine nutrient requirements
- Use palatability enhancers
- Selective breeding for enhanced utilization of alt. ingredients
- Integrated aquaculture/polyculture
- Aquatic microalgae
- More consistent quality products
- Vegetable oil, omega-3 sources for taste and health benefits
- Marine worms-zooplankton–protein and oil
- Bacterial meal from water stream of food processing.
- Converting fuel quality oils to feed quality
- Insects and insect meals
- Essential fatty acid oils (GMO)
- Micro algal and crops
- Black soldier fly meals
- Public perception and barriers to acceptability of alternative ingredients.
- Borage oil
- Yeast base and proteins
- Scavenging long chain fatty acids from algal biodiesel
- Poultry byproducts
- Waste streams of poultry processing
- Organic sources “natural”
- Compositional data for alt. ingredients
- Plant proteins and plant proteins concentrate
- High-DHA algal meal protein & oil
- True value of EPA and DHA to fish
- Byproduct breweries, wineries, farms, and coproducts of biodiesel
- Byproduct from fishery processing waste
- Safe products with utility of optimization

Alternative feed ingredients

The questions posed to this group included:

1. What are potential alternative sources of protein and oil to fish meal and fish oil in aquaculture feeds, and are there specific obstacles to their use in aquaculture feed?
2. What modifications and processes show the most promise for improving the nutritive value of existing aquaculture feedstuffs or developing new feedstuffs, and how close are these technologies to commercialization?
3. What technologies are commercially viable or just technologically feasible to produce a source of long chain omega-3 fatty acids?
4. Who should lead the development and evaluation of alternative diets for aquaculture–industry, universities, government, NGO's, or collaborations of these?

In addressing these questions, the group identified a number of metrics to consider itemized challenges and possible alternative feedstuffs and discussed who should be involved in the research of alternatives feedstuffs. The metrics were as follows:

Key metrics included:

- Economics and logistics of alternative ingredients
- Processing characteristics of alternative ingredients
- Supply and supply efficiencies
- Contaminants in all ingredients
- Public perception and production acceptability
- Immunostimulants
- Fish health–probiotics
- Environmental impact
- Sustainability
- Carbon Footprint

The top priority feedstuffs identified to explore were (several tied for 1st, 2nd and 3rd place):

1 Poultry byproducts
1 Industrial and food byproducts, coproducts
1 Insects and insect meals (e.g. soldier fly)
2 Yeast-based proteins
2 Fishery processing byproducts
3 Micro algal meals–high DHA and proteins
3 Macro algae meals
3 Zooplankton

Future directions for feed manufacturing

The questions that this group was charged with include:

1. What are the high priority needs for feed manufacturing and processing that might be predicted over the next 5 years, based on current agricultural trends, emerging technologies and availability of resources?
2. What can be done, and who should do it (industry, NGO's, government, universities, or a collaboration of these) to strengthen our ability to meet future challenges in manufacture of alternative feeds for aquaculture?
3. What is the most reasonable strategy for near term steps while considering the long-term perspective of ensuring economic viability, environmental quality, and human/animal health?

The research needs for development of future feed manufacturing were identified as follows:

- Fundamental biology
  - o Bioavailability (input/output)
  - o Nutrient requirements
  - o Artisanal aquaculture (niche, organic)
  - o Selection of species (for nutritional value)
- Engineering and technology
  - o System constraints
  - o Methods of extraction of nutrients
  - o Processing technologies
  - o Standardized/cost-effective toxicity testing
  - o Energy inputs, uses and sources
- Market/production
  - o Safety/surveillance
  - o Coordination
  - o Feed conversion efficiency and waste considerations
  - o Regulatory challenges
- Societal needs
  - o Transparency-data research results
  - o Perceptions
  - o Pilot demonstration
- New generation raw materials
  - o Existing (e.g. bycatch)
  - o Emerging

As to who should be supporting, conducting research and communicating results, the group identified the following recommendations:

- All research to be addressed by private industry with government support
- Third party verification of study results
- Research needs to be done by "neutral" organizations

- Government needs to be involved in ingredient-prospecting for novel & non-traditional sources
- Government should support nutrient requirements and update (NRC '93)
- Collaborative work public—private & government academia
- Government should take on selective breeding
- Government should be involved in all the research and disseminate to all
- NGO should support sustainable research on alternate ingredients
- NGO's should aid in education of public acceptance of alternative ingredients

At the end of the discussions and breakout groups, all attendees were asked to complete the following "homework" designed to provide a set of visions for the future of feeds for aquaculture:

> *The Future of Aquafeeds . . .*
>
> *This is a take home assignment – each participant should send in within two weeks following the meeting, what they see happening in the next 5 and 25 years in the area of feeds for aquaculture. This is an exercise in science fiction so please take your best guess and use your imagination but be honest in what you really see as the future of aquafeeds. Please keep each Scenario (5 years from now and 25 years from now) to under 2 pages in length. As much as possible make them applicable to your location and species. Let us know what the diets will be composed of, what the feed efficiency and growth rates will be and what breakthroughs occur to make your scenarios possible. Where will the limiting nutrients come from and what feedstuffs will dominate the industry in your country? What species will these diets be fed to? How much aquafeed is being produced worldwide? How are these diets sustainable in the long run? You are welcome to also put in natural disasters which might affect aquafeeds.*

These "futurecasts" are presented in the next section.